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蓟马诱导的鹅掌柴叶片虫瘿组织的生理生化响应[*]

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摘要：以蓟马诱导的鹅掌柴叶片管状虫瘿为材料，分析了虫瘿和非虫瘿组织的抗氧化活性及其它生理响应以及营养物质的含量、分配等。结果发现虫瘿组织中许多生理指标如过氧化氢浓度、过氧化物酶和苯丙氨酸解氨酶活性以及丙二醛含量都比非虫瘿组织低。虫瘿组织比非虫瘿组织光合速率下降而呼吸速率增强，虫瘿组织转变为一个营养库能够富集较多的营养物质。仅仅使用植物激素和蓟马萃取物不能诱导虫瘿的形成，但是，细胞分裂素类植物生长调节物可以引起类似蓟马诱导虫瘿的早期反应。

关键词：虫瘿诱导，鹅掌柴叶片虫瘿；生理生化响应
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Physiological Responses of Gall Tissues on Ivy Tree Leaves Induced by Thrip

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Abstract：In this research，tuber-like galls which induced by thrip on ivy tree leaves were chosen as materials，and the physiological responses as well as partitioning of mineral nutrition，soluble protein and saccharide contents in galled and un-galled tissues were assayed. Results indicated that compared to the un-galled tissues，galling tissues decreased in many physiological indexes including hydrogen peroxide concentration，Peroxidase and phenylnine amonialase activities and the contents of malondialdehyde. Galling tissues decreased in photosynthetic rate but increased in respiratory rate. Galling tissues acted as a nutritive sink that accumulate more nutrition than surrounding un-galled tissues. Phytohormones and insects extracts alone can not induce the formation of galls，but cytokinins such as kinetin，6-BA and Zeatin can induce responses which are similar to the earlier response of thrip feeding.

Key words：Galling induction；Leafy gall；Plant cell physiological response

Introduction

Galls are the special structures induced by galling makers and could be formed in plant leaves，stems and roots. Galling makers include bacterial，fungi，mites，nematodes and insects. Bacteria-induced galls such as crown galls and root nodules are paid much attention and the formation mechanisms have been demonstrated (Stoyanova and Hamburge，2003；Geurts and Bisseling，2002；Limpens *et al*.，2003). Insect galls are the most common phenomenon and many species of insects have proved to be galling makers. Different species of galling insects induce the production of different types and morphological galls

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(Rohfritsch, 1992; Stone *et al.*, 2003; Dorchin *et al.*, 2002). As plant pests, biology and genetics of galling insects were reported (Abrahamson *et al.*, 2003; Crespi *et al.*, 1998; Fenton *et al.*, 2000; Bjorkman, 2000; Fay *et al.*, 1996), and galls are proved to affect the reallocation of nutrients and galls become vegetative sink in plants (Bagatto *et al.*, 1996; Rehill *et al.*, 2003; Florentine *et al.*, 2005; Koyama *et al.*, 2002). However, little is to know about the formation mechanism, the galling induction substances, and the responses of plant to galling process. Leafy galls on the garden plant ivy tree were frequently seen along street in Kunming, China. Galling thrips can easily, stably and higher efficiently induce the production of galls, by means of feeding. The tuber-like galls can be seen rapidly grow within few days. To study the induction mechanism of gall formation, experiments of gall induction, physiological responses and nutrition allocation in galled and un-galled tissues were assayed in this paper.

1 Materials and methods

1.1 Materials

Ivy tree (*Schefflera heptaphylla* Harms) and galling thrip (*Phlaeothripidae* spp) were chosen as galling formation study model in this research for many advantages. 1) Ivy tree is a common garden plants and can rapidly propagate by vegetable methods; 2) Tuber-like galls induced by thrips on leaves belong to the open type of gall; 3) the activity of the gall and gall maker are easily observed; 4) Gall formation is stable and efficient. Both ivy tree plants and gall-made insect (thrips) were collected from gardens and streets in Kunming, China. Plant materials listed below were collected during July 21－25th in 2007 and used in the experiments: normal young leaves; normal mature leaves, normal old leaves, young galled leaf galled tissues, young galled leaf un-galled tissues, mature galled leaf galled tissues, mature galled leaf un-galled tissues, old galled leaf galled tissues and old galled leaf un-galled tissues. Each sample collected from different site had 8－12 repeats.

1.2 Methods

1.2.1 Gall induction experiments Thrips and active open tuber-like galls are frequently seen on wild ivy tree leaves from spring to autumn. For study the behavior of thrip on ivy tree and the morphogenesis of galls, every 20 gall and insect-free ivy trees (purchased from flower market) were planted and cultured in two different manual atmosphere room, respectively, by branches cutting method at 25℃ with 12 h/12 h light/dark cycles. Ripe thrip insects in ivy tree leaf galls were collected from campus of Yunnan University. In one manual atmosphere room, every thrip was put into one ivy tree on one young leaflet. Main stems of every ivy tree were cycling painted with vaseline to prevent insects from escaping. The activities of the thrip in the ivy tree were carefully observed and recorded. After 1, 2, 3, 4, 5 days, thrips in every three ivy tree were take out, respectively, and the left ivy trees were let continuously co-culture with thrips. Galling responses were observed and recorded every day.

1.2.2 Gall induction experiments by Phytohormone and insect extract For analysis of the roles of phytohormones in gall induction, auxins (3 mg $\cdot$ L^{-1}, 10 mg $\cdot$ L^{-1} of IAA), cytokines (3 mg $\cdot$ L^{-1}, 10 mg $\cdot$ L^{-1} of KT, 6-BA, or zetin), GA (10 mg $\cdot$ L^{-1} GA_3) and their mixtures were used to treat young leaves of ivy trees by micro-injury injection. Insect extracts (extracted from 50 thrips by phosphate buffer) were also used in this experiment. Responses were observed and recorded every day.

1.2.3 Physiological responses assay to plant tissues

(1) Peroxidase (POX) activity assay. POX activity was assayed by using a spectrophotometric procedure. 20 μl of extract were added to 1980 μl of 88.2 mmol $\cdot$ L^{-1} H_2O_2 and 4.6 mmol $\cdot$ L^{-1} guaiacol in 0.1 mol $\cdot$ L^{-1} KSuc, pH 5.5, and vortexed for 5 sec. The increase in absorbance due to the formation of tetraguaiacol was monitored from 0.5 min to 3.5 min at 470 nm., and one unit (U) of POX activity was defined as 0.1 change of absorbance per minute.

(2) Hydrogen peroxide content assay. The concentration of hydrogen peroxide (H_2O_2) was determined as described by Mukherjee and Choudhuri (Mukherjee *et al.*, 1983). Briefly, fresh leaves (0.3 g) were homogenized in 3 ml of refrigerated 10% acetone, the mixture was centrifuged at 10000× *g* for 10 min, and 1 ml supernatant was mixed with 0.1 ml 5% Ti $(SO_4)_2$ and 0.2 ml 35% ammonia. After the precipitate was formed, the reaction mixture was centrifuged at 10000× *g* for 10 min. The resulting pellet was washed with acetone three times and then dissolved in 2 mol $\cdot$ L^{-1} H_2SO_4, and the absorbance was recorded at 415 nm. The H_2O_2 level was calculated according to a standard curve of H_2O_2. The concentration

of H_2O_2 was expressed as mmol · g^{-1} FW.

(3) Phenylalnine ammonialyase (PAL) detection. The PAL assay was conducted by following the procedure of Koukol and Conn (1961). About 1 g of leaf tissues was removed at random, and homogenized in 10 ml of cold solution of 0.05 mol · L^{-1} sodium borate buffer, pH 8.5. The homogenate was filtered through cheese cloth and centrifuged at 14500 × *g* for 30 min. The crude extract was assayed immediately after homogenization. The PAL activity was expressed as the amount (μg per gram tissue dry weight) of cinnamic acid formed. The reaction mixture consisted of 40 mmol of L-phenylalanine, 200 mmol of sodium borate buffer (pH 8.8) and the enzyme solution in a total volume of 5 ml. About 0.1 ml of 6 mol · L^{-1} HCI was used to stop the reaction. The acidified mixture was extracted with ethyl ether and the residue dissolved in 0.05 mol · L^{-1} sodium hydroxide and absorbance was measured at 268 nm.

(4) malondialdehyde (MDA) content detection: Oxidative damage to lipids was expressed as equivalents of malondialdehyde (MDA). MDA content was determined as described by Duan *et al*. (2005). Fresh leaves or tissues (about 0.5 g) were homogenized in 10 ml of 10% trichloroacetic acid (TCA), and centrifuged at 12000 × *g* for 10 min. Then, 2 ml 0.6% thiobarbituric acid (TBA) in 10% TCA was added to an aliquot of 2 ml of the supernatant. The mixture was heated in boiling water for 30 min, and then quickly cooled in an ice bath. After centrifugation at 1000 × *g* for 10 min, the absorbance of the supernatant at 450, 532 and 600 nm was determined with a spectrometer (Libra S22, England). The MDA concentration was estimated using the formula $C\ (\mu mol \cdot L^{-1}) = 6.45\ (A532\text{-}A600)\ \text{-}0.56A450$. The MDA concentration was expressed as μmol · g^{-1} FW.

(5) Photosynthetic and respiratory rate measurement: O_2 releasing rate in 500 μmol · m^{-2} red light and decreasing rate in dark conditions were measured by a oxygen electrode equipment (Oxy-Lab, Hansatech, Egland) to galled and un-galled leaf tissues according to the manuals protocol. Photosynthesis rate was expressed by O_2 increasing rated in unit of time and unit of leaf area (μmol · min^{-1} · m^{-2}). And respiratory rate was expressed by O_2 uptake amount in unit of time and unit mass of tissues.

1.2.4　Detecting nutrient content.

(1) Mineral nutrients analysis: For detection of the mineral elements of evy tree, tissues as described in materials (2.1) were collected and detected by a equipment of ICP (ICP-AES, ICPS-1000II, Japan). Mineral elements contents were expressed as μg/g or mg/g according to the values.

(2) Solvable sugar detection: Soluble sugar was measured as described by Lehner *et al*. (2006). The concentration of soluble sugar was expressed as mg · g^{-1} DW.

(3) Solvable protein content analysis: soluble protein was measured in each sample as described by Bradford (1976) and the concentration was expressed as mg · g^{-1} FW.

(4) C, H, N elements detection: The contents of C, H, and N in drying materials were detected by an organic elements analyzer (Elementar, zario EL III, Germany) according to the manuals protocol.

2　Results

2.1　Gall induction and formation

On ivy tree leaf, tuber-like galls were stably induced by thrips, and thrips and its larvae can be found within an active gall (Fig. 1: A, B). Obvious responses were seen in 1 day after thrips' "treatment". The earlier response produces lighten colored spots (about 6 mm diameter) around the induction sites (Fig. 1: C, D). Enations usually appeared on leaves' opposite of the treated sites within two days. One thrip can induce many leafy galls within one day's. Galls can continuously grow and form into mature galls even when the insects were taken away after few hours treatment (Fig. 1: E, F, G).

2.2　Phytohormone treatment results

Compared to the control, no obvious response was induced when IAA or GA was used alone (Fig. 2: f, g). However, symbols similar to the earlier response (lighten colored spots around the induction site) of thrip induction were found when cytokines such as Zeatin, 6-BA and KT were used (Fig. 2: b, c, d). Contrary to the obvious boundary lighten colored spots induced by insects, lighten colored spots induced by cytokines displayed a vague boundary. No gall was induced or seen any growth of leaf tissues when treated by different type of phytohormones, different hormone composition as well as insects extracts (Fig. 2).

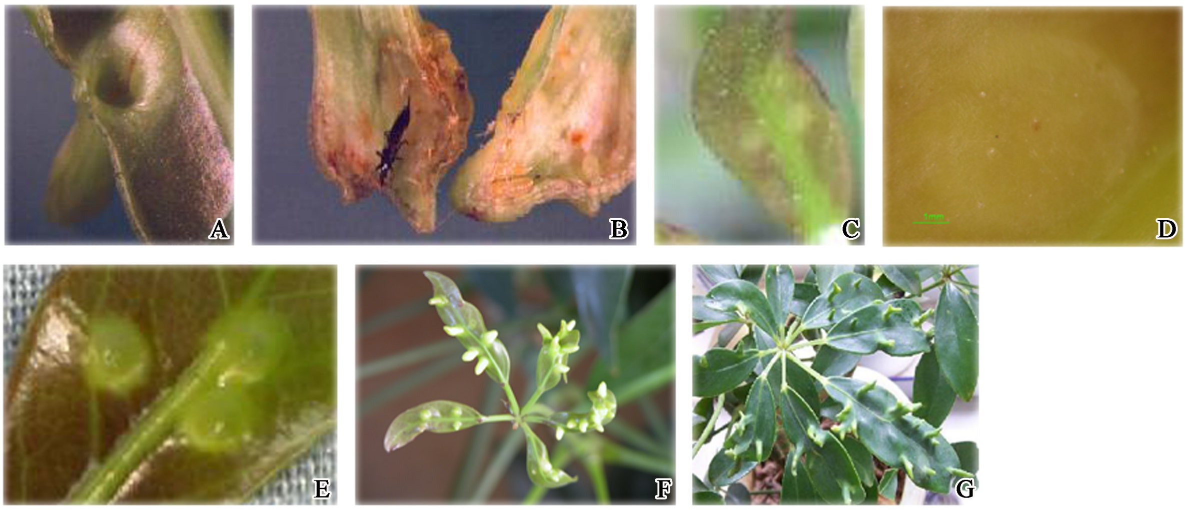
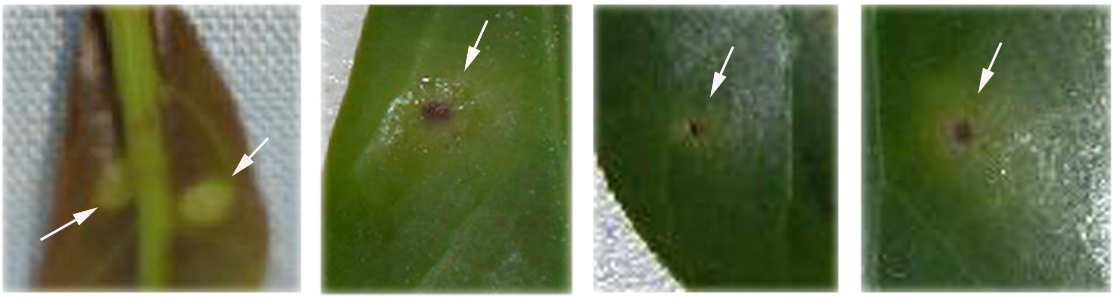
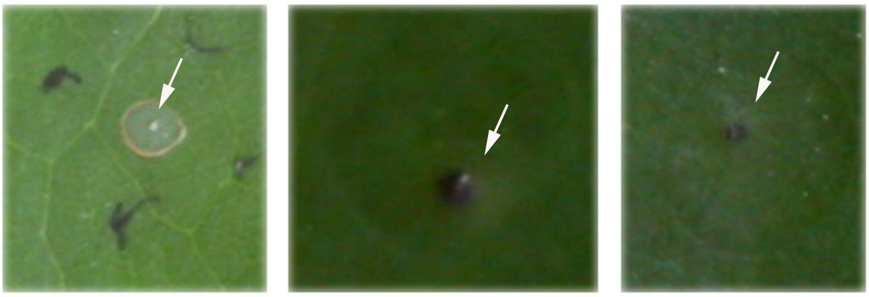


Fig. 1 Thrip induced tuber-like open galls on ivy tree leaves

A. Thrip induced tuber-like open galls; B. Thrips and its larvae can find in a naturally produced active galls; C, D. lighten colored spots around the induction sites was the earlier response of gall induction; E. obviously enations appeared within two days after thrips' treatment; F, G. one day staying of one thrip can induce more than 15 galls in one complex leaf; G. galls can grow maturely without the continuously induction



a. Thrip b. 6-BA c. Zetin d. Katinis



e. Insects extrats f. GA g. IAA

Fig. 2 Phytohormones and thrip extracts induction results

a: The earlier response of life thrip induction; b, c, d: Responses of 6-BA , zeatin and katininis treatment, respectively; e. f, g. Results of thrip extracts, GA and IAA treatment, respectively

2.3 Nutrients allocation in galled and ungelled tissues

Solvable protein, soluable sugar, organic elements and inorganic elements in galled and un-galled tissues were analyzed and illustrated in table 1. Galled tissues contained higher nutrients content than that of the un-galled tissues, especially the content of solvable protein, solvable sugar, total N and the recycled mineral elements, such as phosphate, potassium, Zinc and Boron. Galled tissues displayed relatively low C/N ratio compared to that of the un-galled tissues.

2.4 Physiological metabolism of galling tissues

Photosynthetic and respiratory rate of galled and un-galled tissues were detected by an oxygen electrode instrument. As expected normal mature leaf has more photosynthesis rate than those of normal young and older leaves. The active galled tissues almost have not any photosynthetic ability but the tissues around the galled tissues on the same leaf showed higher photosynthetic rate than the corresponding age′s normal leaf. Respiratory rates decreased along with the leaf age. Therefore, galled tissues have higher intensity of respiratory rates than its surrounding tissues and the active gall tissues have similar intensity of respiratory rates as the normal young leaves (Fig. 3).

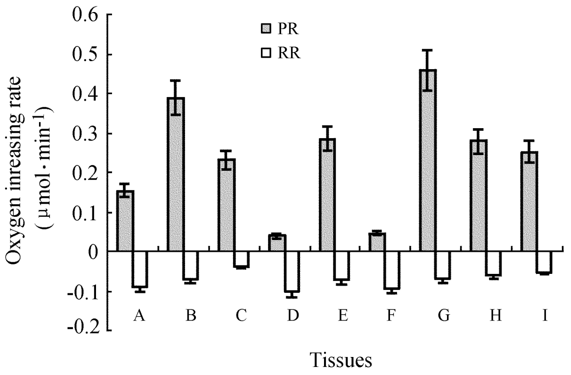


Fig. 3　Photosynthetic and respiratory rates of galled and un-galled tissues

PR: photosynthesis rate; RR: respiratory rate. A-I: different tissue samples as indicated in the notes of table 1

2.5 Stress physiologically response of galling tissues

Normal young and old leaf tissues contain more hydrogen peroxide than that of the mature leaf, as expected. However, galled tissues contain relatively low concentration of hydrogen peroxide than un-galled tissues (Fig. 4: a). Peroxidase activity increases from young to old leaves. However, on all kinds of leaves galled tissues always display lower peroxidase activities than un-galled tissues (Fig. 4: b). Activities of phenylnine amonialase and the contents of malondialdehyde decreased along with the physiological age in normal leaves. The same tendency was also found in galled and un-galled tissues as peroxidase activity and hydrogen peroxide content (Fig. 4: b, d).

Table 1　Content of solvable protein, saccharide, organic and inorganic elements in galled and un-galled tissues

Tissues *	A	B	C	D	E	F	G	H	I
Soluable protein (mg/g)	4.52±0.7	3.16±0.5	3.02±0.3	5.87±0.5	5.14±0.5	3.79±0.4	2.57±0.3	4.72±0.4	4.45±0.5
Soluable sugar (mg/g)	111.76±9.4	101.19±11.5	94.46±8.5	68.80±6.7	47.42±7.5	108.74±6.4	93.77±7.3	74.57±5.9	52.89±5.7
Total N (%)	3.85±0.3	3.14±0.3	2.80±0.3	3.87±0.3	3.67±0.7	2.93±0.2	2.75±0.3	2.61±0.2	2.63±0.3
Total C (%)	46.37±5.5	48.24±4.3	50.51±5.7	46.32±5.1	46.00±5.0	48.03±4.7	46.4±4.3	45.19±4.4	44.43±4.2
C/N ratio	12.03±0.9	15.36±1.4	18.05±1.5	11.97±1.1	12.54±0.9	16.41±1.3	16.85±1.2	17.30±1.1	16.91±1.6
Ca (mg/g dw)	5.46±0.4	9.95±0.7	12.70±0.3	2.87±0.1	4.91±0.3	3.59±0.4	10.20±0.7	4.49±0.3	9.64±0.2
P (mg/g)	1.51±0.1	0.58±0.1	0.65±0.1	1.54±0.1	1.08±0.1	1.17±0.1	0.70±0.1	0.91±0.1	0.65±0.1
K (μg/g)	7.01±0.5	7.28±0.9	7.77±0.6	9.03±0.8	4.33±0.7	10.60±0.6	9.90±0.5	9.78±0.8	8.53±0.7
Fe (μg/g)	36.48±1.5	52.47±2.3	50.17±2.6	72.13±2.7	65.08±4.5	89.13±4.9	105.00±8.3	111.00±8.2	69.70±3.9
S (μg/g)	387±19	372±25	625±22	318±31	343±21	268±18	278±13	230±21	197±20
Mg (mg/g)	2.25±0.1	3.75±0.1	1.67±0.1	2.39±0.1	1.73±0.1	1.66±0.3	2.53±0.2	1.66±0.2	1.63±0.1
Mn (μg/g)	75±6.3	146±19	54±7	88±7	97±6	78±5	168±9	50±4	34±6
B (μg/g)	34±2	27±3	58±3	24±2	22±3	21±2	16±1	15±2	15±1
Zn (mg/g)	9.73±0.5	23.22±0.7	12.24±2.2	11.00±1	7.27±0.5	13.88±0.8	6.44±0.7	14.67±0.3	11.53±0.7

"*" Tissue samples notes: A: normal young leaf; B: normal mature leaf; C: normal old leaf; D: young galled leaf galled tissues; E: young galled leaf un-galled tissues; F: mature galled leaf galled tissues; G: mature galled leaf un-galled tissues; H: old galled leaf galled tissues; I: old galled leaf un-galled tissues

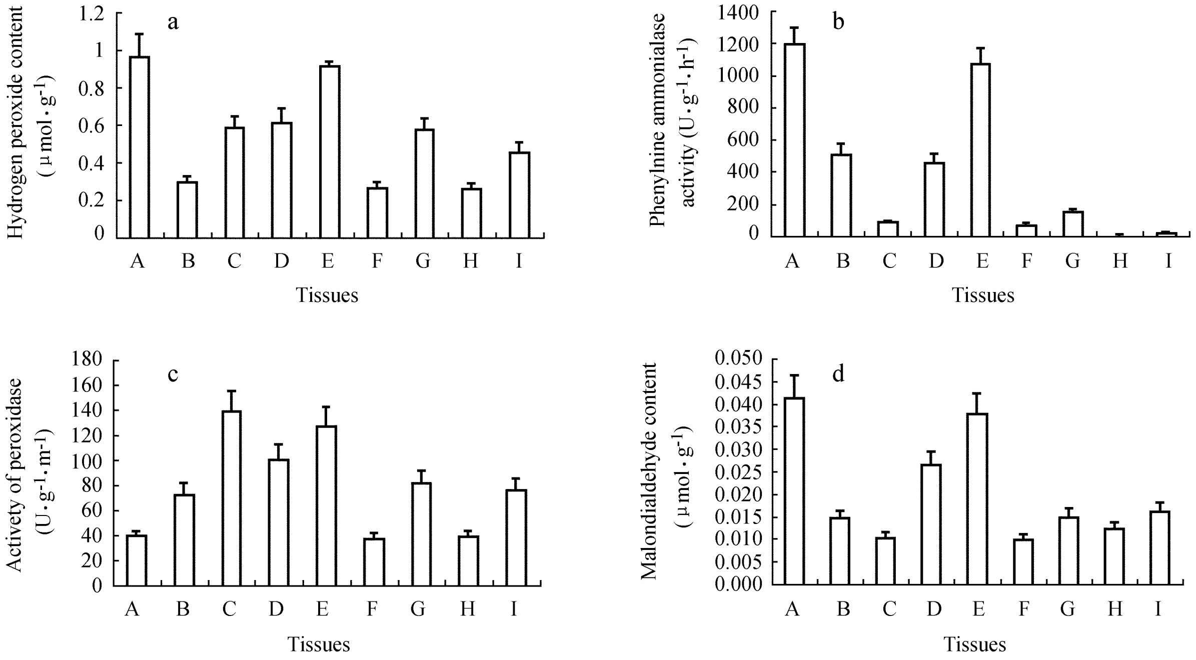


Fig. 4 Physiological responses of galled and un-galled tissues of ivy tree leaves

A-I: different tissue samples as indicated in the notes of table 1

3 Discussion

Traditionally many gall making insects have been studied as plant pest, (Rohfritsch, 1992; Abrol *et al.*, 2006; Protasov *et al.*, 2007; Lvarez *et al.*, 2009), and research works mainly have focused on gall morphological (Stone and Schonrogge, 2003; Arduin *et al.*, 2005), damage of gall to plant (Abrol *et al.*, 2006) and so on. The morphological of galls are considered to be determined by the genetic characters of galling makers (Brantner *et al.*, 2000; Stone and Schonrogge, 2003; Arduin *et al.*, 2005). However, gall formation mechanisms still remain unclear. Galls may be induced by insects or microorganisms. Nodules and crown galls are the frequently seen microbe-induced galls. Nodules are induced by nitrogen-fixing *Rhizobium* and the nodule induction factor is identified and proved to be one of the plant endogenous substances (Geurts and Biseeling, 2002; Limpens *et al.*, 2003). Studies on the crown gall lead to the findings of plant cytokines and the broadly application of transgenic tool (T-DNA). It is well known that, abnormal growth of plant such as phototropism, crown gall and Banakae Disease, lead to the findings and deeply understanding of plant endogenous regulators of IAA, cytokine and GA, respectively. What may tell us that so many types of galls induced by insects?

Conveniently propagation of ivy tree plant, widely seen of gall and galling thrip, rapidly galling respond, higher efficiency of induction and easily observation make open tuber-like leafy gall induced by thrip a good model in plant-insect interaction study. In this case, we focused on the plant responses during galling induction and formation. As described in other type of galls (Bagatto *et al.*, 1996; Rehill and Schultz, 2003; Florentine *et al.*, 2005; Koyama *et al.*, 2002), galling tissues concentrated more nutrients such as solvable proteins, solvable saccharide, Nitrogen, phosphate, potassium than surrounding un-galled tissues (Table 1). Galling events leaded to the reallocation of nutrients. But the average content of many nutrients within galled leaves was lower than that of the normal corresponding stage leaves. It implied that nutrient reallocation was mostly restricted within the nearing tissues and organs. However, one question is how plant cells respond to the action of galling insects. In normal conditions, when disease or pest threatens a plant, plant cells respond as be resistant or susceptible. No matter resistant or susceptible response, plant cells often respond with increse of ROs (reactive oxidates) stress, anti-oxidase activities. MDA content may increase for oxidative damage to lipids. In this research, content of hydrogen peroxide, MDA contents and the activities of PAL, POX were all seen obviously decreased or inhibited. All these indexes above were seen lower in galling leaves than that of un-galled or normal leaves. These results means that the galling plant has not see any evidences to injury or resistance.

We hypothesized here that the substances which galling insects used in plant galling induction may be a kind of plant cell endogenous components, and act in the far upstream of gall induction. The content and production of these substances are under strictly controlling in normal un-galled plant cells. Exogenous introduction of these kinds of substances leads to the changes both in plant cell metabolism and phytohormone equilibrium, and consequently, the gall is formed. With this hypothesis, all of the results can be reasonably explained. Because the galling induction substances are endogenous compounds and plant treats these molecules as endogenous signals, no resistant response is detected. Direct evidences come from the mechanism of root nodule and crown gall formation. Rhizobium nod factor (a kind of low molecular polysaccharide) which produced by root nodule bacterial has been proved as one of the plant cell endogenous signal (Engler *et al*., 1999). Agrobacteria can directly transform plant cytokines gene into plant cell and lead to the formation of crown galls (Lynn *et al*., 1987). It is not a new story that pests, pathogens or other plant symbiotic organism own plant endogenous regulator as its benefit. On the other side, studies on the interaction between plant and its enemies also dramatically broadened our knowledge to plant. For plant hormones, many of them may be involved during the formation of galls, especially the plant cell growth and division enhancing hormones. It is indirect evidence that cytokines types of phytohormone such as 6-BA, KT and Zeatin can induce responses similar to the earlier induction by thrips. Earlier reports demonstrated that endogenous phytohormones were detected and found 17 times more auxin activity and as much as 21 times more gibberellin-like activity in galling tissues than normal tissues (Byers *et al*., 1976). Cytokines is also found to increase in ball galls (Mapes and Davies, 2001). So, phytohormones may act to downstream this signal pathway during gall induction. Root nod inducing factors as a signal that accepted by cellular receptors then mediate the nodule formation has been demonstrated (Geurts *et al*., 2002; Limpens *et al*., 2003). Genes within host plant have been proved affecting the interaction of gall midge and rice (Limaa *et al*., 2007). For nutrient reallocation, a nutrients hypothesis is provided to explain the formation mechanism of galls (Koyama *et al*., 2004). But galls becoming a mobile vegetable sink may also be the response to the higher contents of phytohormones, because many of the plant growth enhancing hormones such as IAA, CTK, GA and so on are involved in the nutrients partitioning regulation.

Multiple morphological galls are induced by different type of galling insects and different galling insects may produce different type of gall induction substance and creating different patterns of cellular equilibrium of plant regulators during the gall induction process. So, identification, functioning of these trace existing substances may deeply and widely improve our understanding of plant cell division and growth regulating mechanism.

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References:

Abrahamson WG, Hunter MD, Melika G *et al*., 2003. Cynipid gall-wasp comunites correlate with oak chemistry [J]. *Journal of Chemical Ecology*, **29**: 209—223

Arduin M, Fernandes GW, Kraus JE *et al.*, 2005. Morphogenesis of galls induced by Baccharopelma dracunculifoliae (Hemiptera: Psyllidae) on *Baccharis dracunculifolia* (Asteraceae) leaves [J]. *Brazilian Journal of Biology*, **65**: 559—571

Abrol DP, Ramamurthy VV, Srivastava K, 2006. Bean gall weevil and blister beetle as new pests on red kidney bean (*Phaseo/us vulgaris* L.) in India [J]. *Journal of Asia-Pacific Entomology*, **9**: 317—320

Bagatto G, Paquette LC, Shorthouse JD, 1996. Influence of galls of phanacis taraxaci on carbon partitioning within common dandelion, Taxacum officinale. Entomol [J]. *Entomdogia Experimentalis et Applicata*, **79**: 111—117

Bjorkman C, 2000. Interactive effects of host resistance and drought stress on the performance of a gall-making aphid living on Norway spruce [J]. *Oecologia*, **123**: 223—231

Bradford MM, 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein dye-binding [J]. *Annals of Biochemistry*, **72**: 248—254

Brantner AH, Asres K, Chakraborty H *et al.*, 2000. Diversity of insect-induced galls along a temperature-rainfall gradient in the tropical savannah region of the Northern territory, Australia [J]. *Austral Ecology*, **25**: 311—318

Byers JA, Brewer JW, Denna DW, 1976. Plant growth hormones in pinyon insect galls [J]. *Marcellia*, **39**: 125—134

Crespi BJ, Carmean DA, Mound LA *et al.*, 1998. Phylogenetic of Social behavior in Australian gall-forming Thrips: Evidence from mitochondrial DNA sequence, Adult morphology and behavior, and gall morphology [J]. *Molecular Phylogenetics and Evolution*, **9**: 163—180

Dorchin N, Freidberg A, Aloni R, 2002. Morphogenesis of stem gall tissues induced by larvae of two cecidomyiid species (Diptera: Cecidomyiidae) on *Suaeda monoica* (Chenopodiaceae) [J]. *Canadian Journal of Botany*, **80**: 1141—1150

Duan B, Lu Y, Yin C *et al.*, 2005. Physiological responses to drought and shade in two contrasting *Picea asperata* populations [J]. *Physiologia Plantarum*, **124**: 476—484

Engler JA, Celenza JL, 1999. Molecular markers and cell cycle inhibitors show the importance of cell cycle progression in nematode-induced galls and syncytia [J]. *The Plant Cell*, **11**: 793—808

Fay PA, Hartnett DC, Knapp AK, 1996. Plant tolerance of gall-insect attack and gall-insect performance [J]. *Ecology*, **77**: 521—534

Fenton B, Birch ANE, Malloch G *et al.*, 2000. Gall mite molecular phylogeny and its relationship to the evolution of plant host specificity [J]. *Experimental and Applied Acarology*, **24**: 831—861

Florentine SK, Raman A, Dhileepan K, 2005. Effects of gall induction by *Epiblema strenuana* on gas exchange, nutrients, and energetics in *Parthenium hysterophorus* [J]. *BioControl*, **50**: 787—801

Geurts R, Bisseling T, 2002. Rhizobium Nod factor perception and signaling [J]. *The Plant Cell*, **14**: 239—249

Koukol J, Conn E, 1961. The metabolism of aromatic compounds in higher plants. IV. Purification and properties of the phenylalanine deaminase of *Hordeum vulgare* [J] *Journal of Biochemisty*, **236**: 2692—2698

Koyama Y, Yao I, Akimoto SI, 2004. Aphid galls accumulate high concentrations of amino acids: a support for the nutrition hypothesis for gall formation [J]. *Entomologia Experimentalis et Applicata*, **113**: 35—44

Lehner A, Bailly C, Flechel B *et al.*, 2006. Changes in wheat seed germination ability, soluble carbohydrate and antioxidant enzyme activities in the embryo during the desiccation phase of maturation [J]. *Journal of Cereal Science*, **4**: 175—182

Limaa JM, Dassa A, Sahub SC *et al.*, 2007. A RAPD marker identified a susceptible specific locus for gall midge resistance gene in rice cultivar ARC5984 [J]. *Crop Protection*, **26**: 1431—1435

Limpens E, Franken C, Mit PS *et al.*, 2003. LysM domain receptor kinases regulating rhizobial nod factor-induced infection [J]. *Science*, **302**: 630—633

Lvarez RA, Encina A, Pe'rez Hidalgo N, 2009. Histological aspects of three *Pistacia terebinthus* galls induced by three different aphids: *Paracletus cimiciformis*, *Forda marginata* and *Forda formicaria* [J]. *Plant Science*, **176**: 303—314

Lynn DG, Chen RH, Manning KS *et al.*, 1987. The structural characterization of endogenous factors from *Vinca rosea* crown gall tumors that promote cell division of tobacco cells [J]. *Proceedings of the National Academy of Sciences of the United States of America*, **84**: 625—629

Mapes CC, Davies PJ, 2001. Cytokinins in the ball gall of *Solidago altissima* and in the gall forming larvae of *Eurosta solidaginis* [J]. *New Phytologist*, **151**: 203—212

Mukherjee SP, Choudhuri MA, 1983. Implications of water stress-induced changes in the levels of endogenous ascorbic acid and hydrogen peroxide in vigna seedlings [J]. *Physiologia Plantarum*, **58**: 166—170

Protasov A, Blumberg D, Brand D *et al.*, 2007. Biological control of the eucalyptus gall wasp *Ophelimus maskelli* (Ashmead): Taxonomy and biology of the parasitoid species *Closterocerus chamaeleon* (Girault), with information on its establishment in Israel [J]. *Biology Control*, **42**: 196—206

Rehill BJ, Schultz J, 2003. Enhanced invertase activities in the galls of *Hormaphis hamamelidis* [J]. *Journal of Chemical Ecology*, **29**: 2703—2720

Rohfritsch O, 1992. Patterns in Gall Development [A]. In: Shorthouse JD, Rohfritsch O eds., Biology of Insect-induced Galls [M]. New York: Oxford University Press, 60—86

Stone GM, Schonrogge K, 2003. The adaptive significance of insect gall morphology [J]. *Trend in Ecology & Evolution*, **18**: 512—522

Stoyanova S, Hamburger M, 2003. Crown gall-a plant tumour with biological activities [J]. *Phytotherapy Research*, **17**: 385—390